The View from Elsewhere

The Emerging Need for Non-LEO Vantage Points

Mark Schoeberl & Peter Hildebrand & Jay Herman

NASA, Goddard Space Flight Center

&

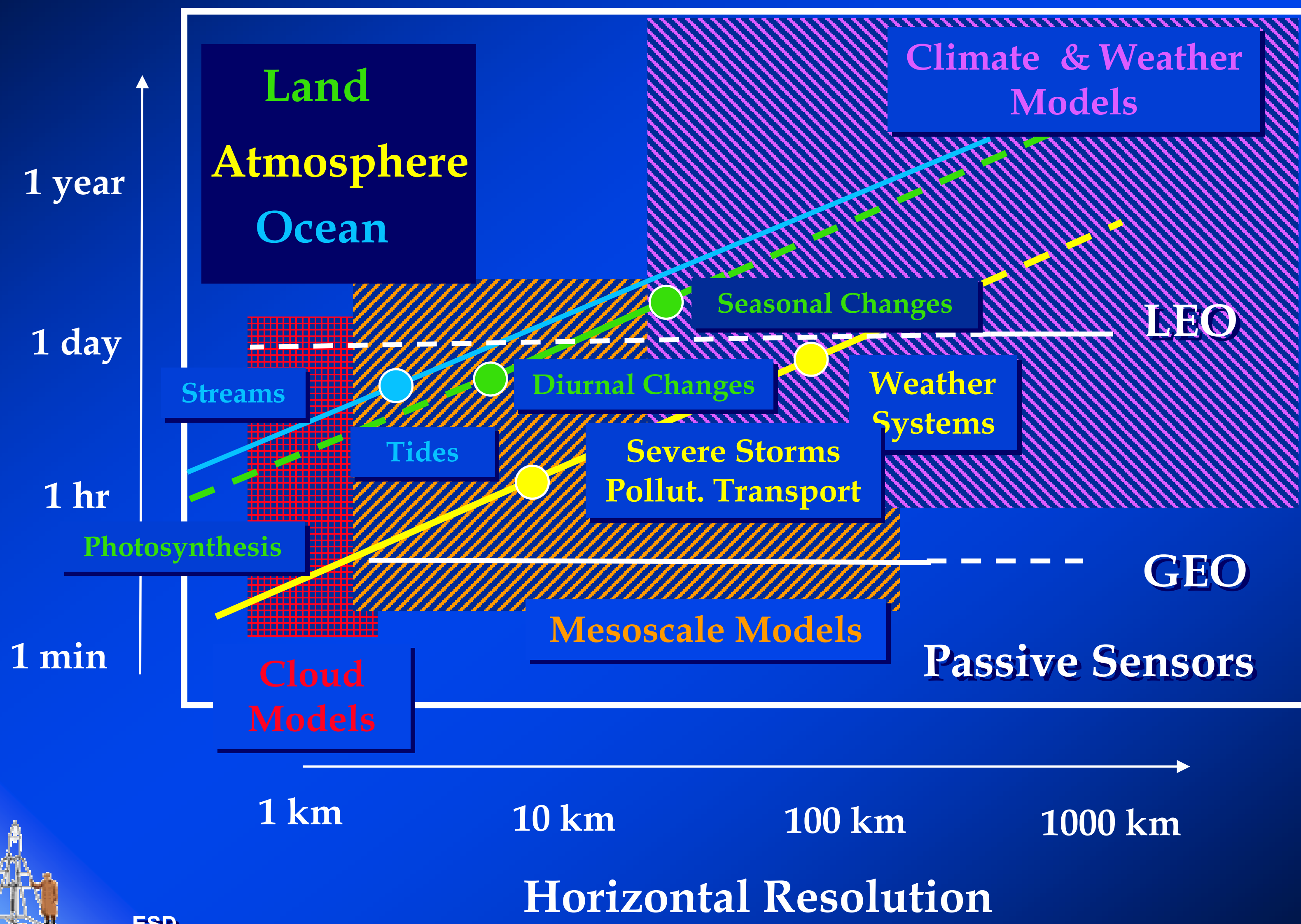
Carol Raymond

NASA, Jet Propulsion Laboratory

Science Drivers

- Choice of vantage point should be driven by science needs
- Some generalized science requirements that drive choice of vantage points
  - High spatial resolution (~ 1 km or less)
  - High vertical resolution (~ 1/2 km or less)
  - Need for active soundings (lidar, radar)
  - High temporal resolution (~15 minutes)
  - Global coverage
- Instrument Requirements
  - Spectral range (Radio->UV)
  - Need absorption measurements
    - Solar/stellar/lunar occultation
    - Sun glint
    - Artificial sources (e.g. GPS)
  - Need emission measurements

Spatial and Temporal Requirements for Earth Science



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Some ES Measurement Needs

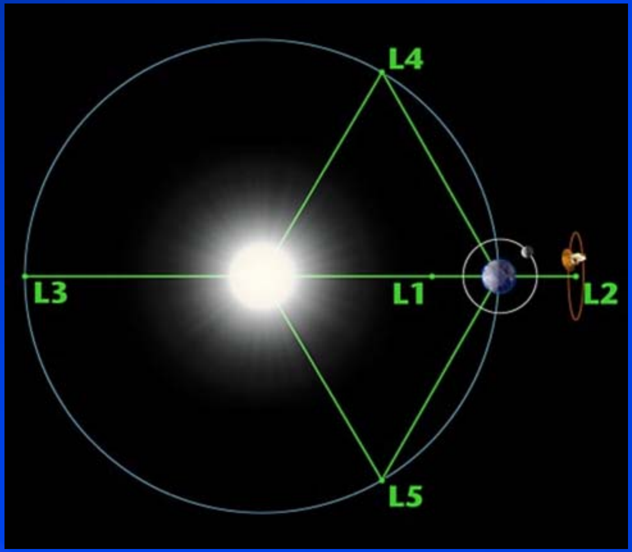
Technique

	UV/Vis	NIR	TIR	µ	lidar	radar	radio	Non photonic
• **Existing Measurements**								
– Temperature / Moist			x	x	x		x	
– Aerosols	x	x						
– Vegetation canopy					x	x		
– Vegetation types	x	x	x	x				
– Crustal stress						x		
– Ocean height						x		x
– Ice sheet/ Land height					x	x		x
– Trace gases	x	x	x	x	x			
• **New Measurements**								
– Winds	x			x	x	x		
– Ocean salinity				x				
– Soil moisture				x		x		
– Ocean mixed layer depth					?			

Any vantage point (UV/Vis, NIR, TIR) — Mostly LEO (µ, lidar, radar, radio, Non photonic)

Orbit Types Discussed Here

- Low Earth Orbit (400-900 km)
- Geostationary (Geosynchronous) (~36,000 km)
- L1 (Full sunlit disk) (~1,500,000 km)
- L2 (Earth limb solar occultation) (~1,500,000 km)



L1, L2 Unstable Lagrange Points

L4, L5 The Trojan points (stable)

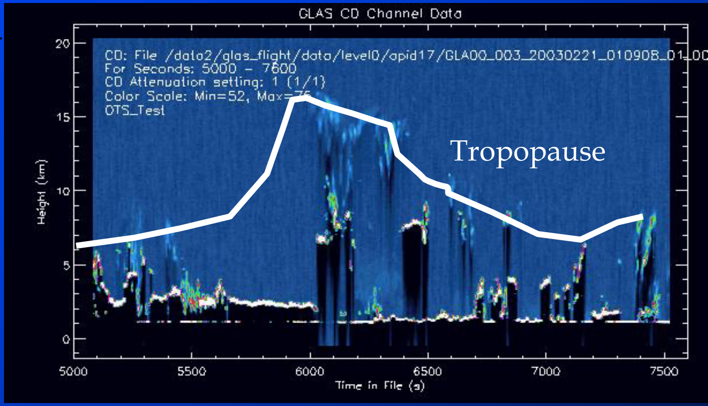
Low Earth Orbit (LEO)

- Advantages
  - Polar sun synchronous
    - Provides global coverage once a day (reflected light) or twice a day (active sounders or thermal IR)
    - Provides ~14 solar occultations a day at high latitudes
  - Mid to Low -inclination
    - Provides more observations per day (between 2-14)
    - Provides ~ 14 occultations per day at varying latitudes
  - Satellites can be reached by the shuttle (e.g. HST)
  - Active sensors (radars and lidars) can operate easily from low orbit
- Disadvantages
  - One to two observations per day gives poor time resolution for rapidly changing phenomena
  - Global orbit-to-orbit coverage once per day requires a wide field of view instrument
  - Unless special X-band receivers are available, data may have a 1-2 hour latency.

Active Systems

- **Lidars**
  - Advantages
    - Altitude resolution of measurements
    - Specific constituents (aerosols)
    - Winds
  - Technology challenges
    - Spatial coverage
  - Advantages
    - Lots of new types of measurements (soil moisture, ocean salinity, snow, etc.)
    - All weather for some types of measurements
  - Technology challenges
    - Large antennas needed for high spatial resolution
    - Frequencies higher than 640 GHz still challenging

IceSat



Results from GLAS

400-900 km

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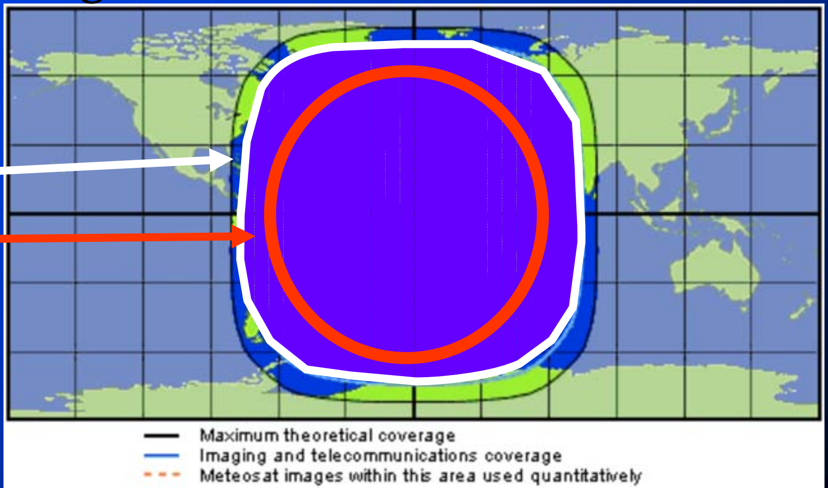
Geostationary

- Advantages
  - Provides high time resolution observations
  - Can stare to gather photons
    - 1 km Resolution at LEO => 1/7 second photon gathering time
    - In GEO, the same number of photons can be gathered in ~10 m
    - But will need larger aperture to scan the whole region in ~15 min
  - Reduced cloud interference
- Disadvantages
  - Coverage of only about 1/5 or the earth from a single satellite
    - Drifting GEO (1 week orbit) solves some of this
  - No polar coverage
  - Issues with pointing and geo-referencing

Image coverage range

Coverage range for quantitative data

(35,875 km)



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Why GEO?

GOES

QuickTime™ and a DV/DVCPRO - NTSC decompressor are needed to see this picture.

SeaWIFS July 6

SeaWIFS July 7

SeaWIFS July 8

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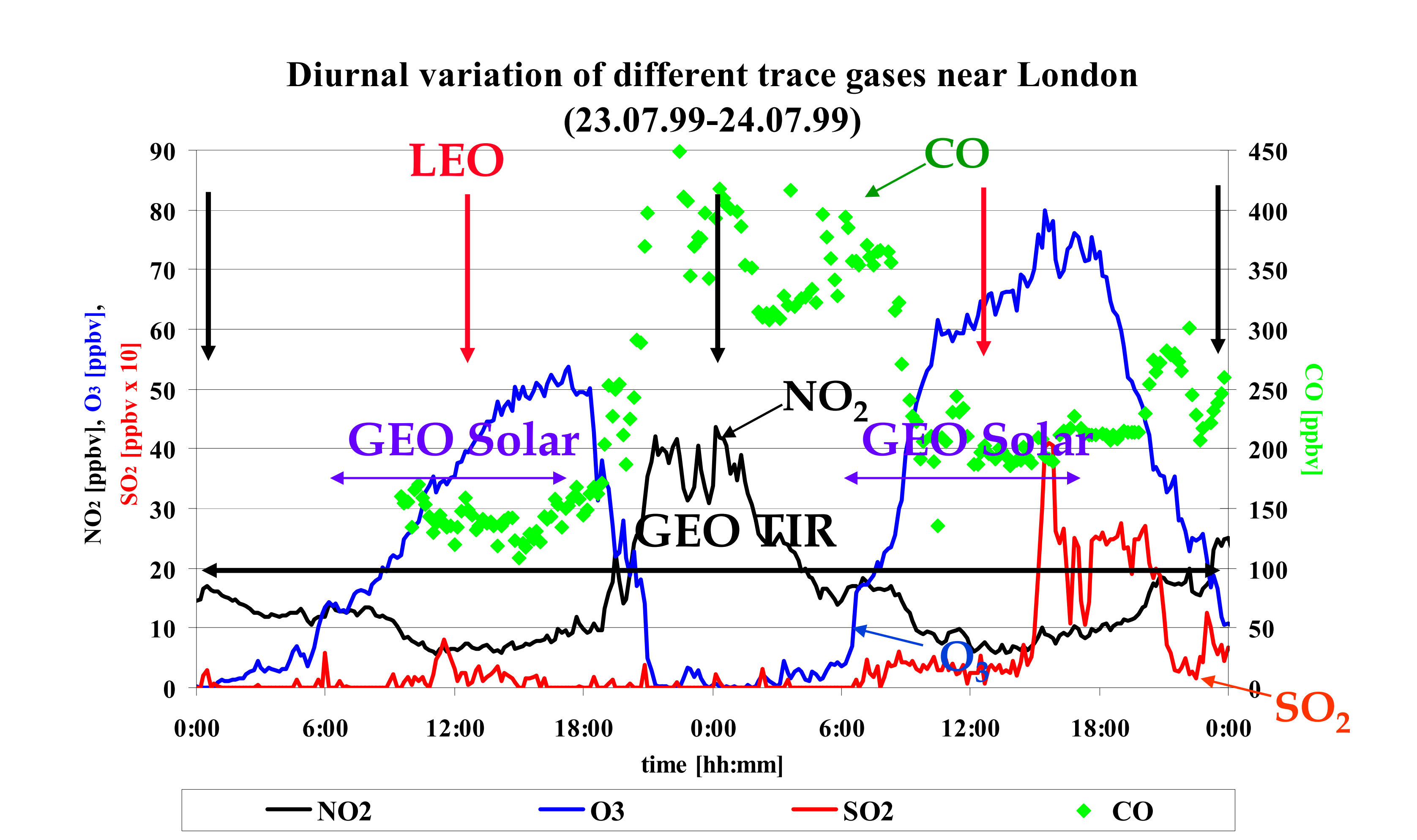
Daily Variability of Air Pollution



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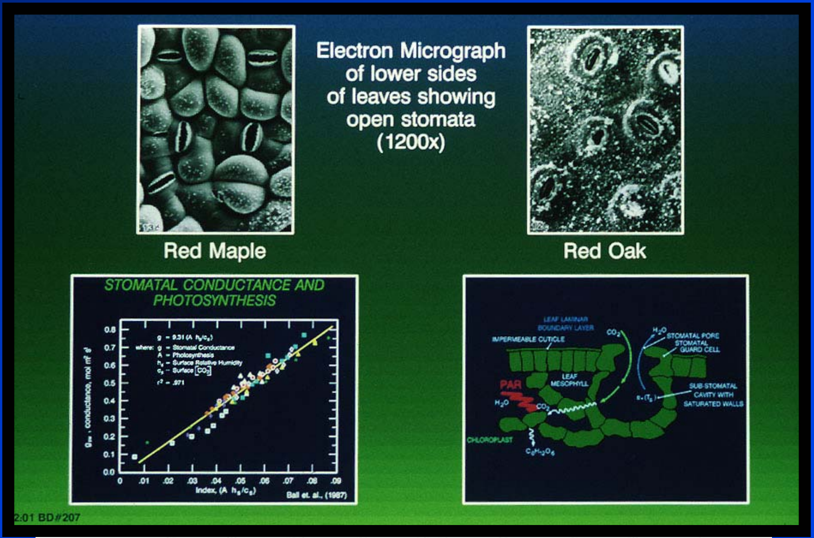
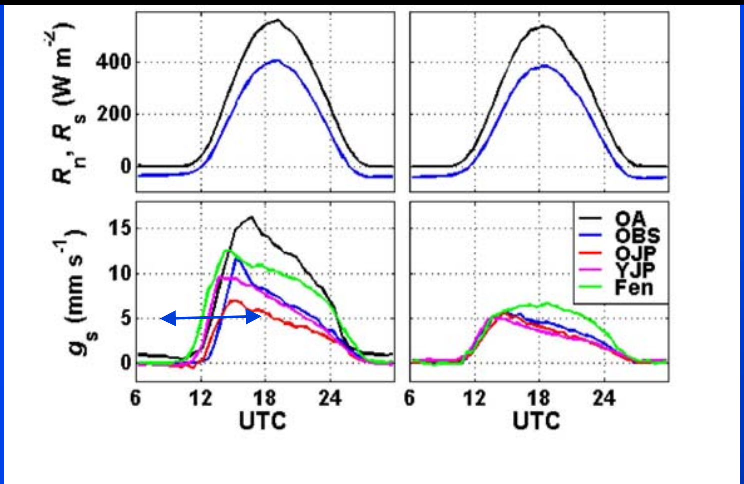
Diurnal Variation in Atmosphere-Surface Mass/Energy Exchange - a Key Process in Carbon and Water Cycling

Carbon Uptake C
Evapotranspiration E





Stomatal Regulation Links ET and C

Stomata open in response to light.

Stomata close in response to moisture stress, excess leaf temperature, and low humidity.

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Some Example System Requirements for a Future GEO System

Data Flow

Assume 100 channels (bands - MODIS has 36)

Observations made every 15 minutes

Pixel Resolution 200m, 16 bits/pixel

One satellite sees 1/5 or the earth

Total data rate needed = 2×10^{10} bits/s per satellite

20 gigabits/second - can't be done with X Band (0.15 gbs)

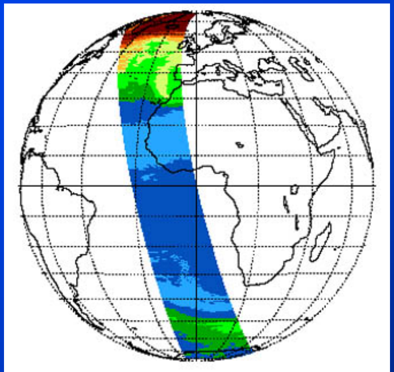
Optical relays or future Ka band = 2 gigabits/s

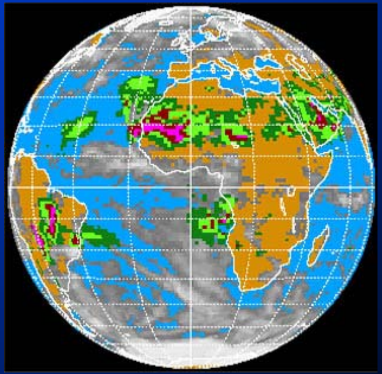
Need to move to optical or Ka band downlinks or more onboard compression and processing. These will be major drivers of future systems.

Lagrange Point - L1

Triana/DSCOVR
L1 Mission

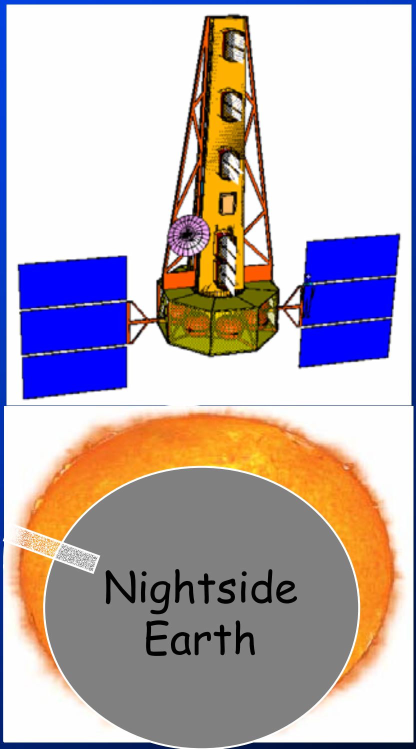
- <u>L1 provides an ideal platform for reflected sunlight observations</u>
- Advantages
  - Near global coverage once a day
  - Improved signal to noise through staring
  - Reduced cloud interference
  - Narrow Field of View (0.5^o) simplifies optical design
  - Moon calibration, enabling delicate global change measurements spanning many years
  - No shadows
- Disadvantages
  - Limited spatial resolution vs exposure because of 0.5 km/sec Earth rotation at equator
  - Limited polar observations
- Technology challenges
  - Geo-referencing
  - Data rates





Lagrange Point - L2

- L2 permits solar occultation of the Earth's atmosphere from visible to 4 µ
- Advantages
  - Near global coverage once a day (0.1° latitude x 2° longitude)
  - High resolution for altitude profiles (1 to 2 km)
  - Good sensitivity for greenhouse gases
  - Can observe from middle troposphere to middle stratosphere (50 km)
- Disadvantages
  - Requires large (up to 8 meter) interferometer
  - Lowest altitude is 8 km
- Technology challenges
  - High speed closed loop control for Active Optics
  - Data rates
  - Thermal control of instrument



Future Observing Systems

- LEO visible and IR sensor capability will be migrating to GEO, L1 and L2
- Advantages
  - Improved time resolution
  - Equivalent spatial resolution
  - Improved signal to noise through staring
  - Reduced cloud interference
- Disadvantages
  - Multi-platform needed for global coverage
  - Fewer polar observations
  - Too far out for active systems
- Technology challenges
  - Geo-referencing
  - Data rates
  - Large apertures needed for passive μ-wave
- Active Sensors will stay at LEO in the near future
  - For Geo need 3600x more power for lidars and radars assuming current resolution and S/N